USAARL Report 76-14

VISIBLE AND NEAR INFRARED SPECTRAL TRANSMISSION CHARACTERISTICS OF WINDSCREENS IN ARMY AIRCRAFT

By

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February 1976

Final Report

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAARL Report No. 76-14	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) VISIBLE AND NEAR INFRARED SPECTRAL TRANSMISSION CHARACTERISTICS OF WINDSCREENS IN ARMY AIRCRAFT		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Wun C. Chiou, Ph.D.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bio-Optics Division (SGRD-UAO) US Army Aeromedical Research Laboratory Fort Rucker, AL 36362		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA 1498
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Aeromedical Research Laboratory SGRD-UAC Fort Rucker, AL 36362		12. REPORT DATE February 1976
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) US Army Medical R & D Command Washington, DC		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Spectral transmittance
Army aircraft windscreen
Visible spectrum
Near infrared spectrum

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents an analysis of the spectral transmission characteristics from 360 to 1080 nm spectral range of sixteen Army aircraft windscreen samples. Those samples were from six fixed wing and seven rotary wing aircraft windscreens. We have found that the spectral transmittance varies from sample to sample in the visible portion of the spectrum (i.e., 360-700 nm) and remains quite flat for all the samples across the near infrared portion of the spectrum (i.e., 700 - 1080 nm). The tinted sample in AH-1 Hueycobra has about

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27% reduction from that of the clear one across the visible spectrum. This reduction could constitute a dangerous loss of visibility for the aviator during periods of reduced illumination and at night. Furthermore, the variance from a flat spectral transmission would result in distorted color perception by the aviator viewing through the tinted windscreen. In short, the reference data enable potential users of electro-optical devices such as night vision goggles to compute the light stimulus presented to the aviator after transmission through a transparency.

SUMMARY

This report presents an analysis of the spectral transmission characteristics from 360 to 1080 nm spectral range of sixteen Army aircraft windscreen samples. Those samples were from six fixed wing and seven rotary wing aircraft windscreens. We have found that the spectral transmittance varies from sample to sample in the visible portion of the spectrum (i.e., 360-700 nm) and remains quite flat for all the samples across the near infrared portion of the spectrum (i.e., 700 - 1080 nm). The tinted sample in AH-1 Hueycobra has about 27% reduction from that of the clear one across the visible spectrum. This reduction could constitute a dangerous loss of visibility for the aviator during periods of reduced illumination and at night. Furthermore, the variance from a flat spectral transmission would result in distorted color perception by the aviator viewing through the tinted windscreen. In short, the reference data enable potential users of electro-optical devices such as night vision goggles to compute the light stimulus presented to the aviator after transmission through a transparency.

Robert W. Bailey

ROBERT W. BAILEY
Colonel, MSC
Commanding

INTRODUCTION

The increasing application of electro-optical devices such as night vision goggles as aids in night flight training promptly demands a prerequisite evaluation of the optical quality and the visual detection thresholds of those devices when they are viewed through the aircraft windscreen. As a consequence, it is important to investigate the spectral transmission characteristics of aircraft windscreens in current Army inventory. The data enable potential users of electro-optical devices to compute the amount of available visible as well as near infrared radiation energy being transmitted through the windscreens to the image intensifier tube.

Over the last few months, we have measured windscreen spectral transmittances from 400 to 800 nm[1,2] and from 700 to 1100 nm[3,4]. This report presents a list of windscreen spectral transmittances of six fixed wing and seven rotary wing Army aircraft which is not available elsewhere in the literature.

METHODOLOGY

a. Samples:

(1) The Fixed Wing Aircraft (total seven samples).

(a) O-1 (Bird Dog) - A two-place liaison/observation aircraft manufactured by Cessna Aircraft Co., Wichita, Kansas.

(b) OV-1 (Mohawk) - A two-place observation/surveillance airplane made by Gruman Aircraft Engineering Co., Bethpage, Long Island, N.Y.

(c) U6 (Beaver) - A six-place utility aircraft by de Havilland Aircraft of Canada, Ltd., Downsview, Ontario.

(d) T-41 - A four-place, single engine trainer by Cessna Aircraft Co., Witchita, Kansas (formed edge sample).

(e) T-41 (flat/unformed edge sample).

(f) T-42 - A four-place instrument/transition trainer by Beech Aircraft Corp., Wichita, Kansas.

(2) The Rotary Wing Aircraft (total eight samples).

(a) TH-13 (Sioux) - A three-place observation/training helicopter (OH-13 T Model) made by Bell Helicopter Co., Fort Worth, Texas.

(b) TH-55/OH-6A - TH-55 is a two-place primary trainer helicopter by Hughes Tool Co., Aircraft Div., Culver City, CA. OH-6A (Cayuse) is a four-place light observation helicopter also manufactured by Hughes Tool Co.

(c) OH-58 (Kiowa) - A four-seated observation helicopter by Bell Helicopter Co., Fort Worth, Texas.

(d) CH-47 (Chinook) - A medium transport helicopter by Boeing Vertol Division, Morton, PA.

(e) CH-54 (Tarhe) - A heavy lift cargo helicopter by Sikorsky Aircraft Division, Stratford, Conn. (The same windscreen material is also used in CH-34 [Choctaw] and CH-37 [Mojave] helicopters manufactured also by Sikorsky Aircraft Division.)

(f) UH-1 (Iroquois [nickname Huey]) - A nine-place utility helicopter by Bell Helicopter Co., Fort Worth, Texas.

(g) AH-1G (Hueycobra) - A two-place armed helicopter by Bell Helicopter (the sample is a clear transparent color).

(h) AH-1G (tinted sample).

All the sample dimensions are 2 X 2 inches except the one for CH-47 is 3 X 3 inches.

b. Apparatus - The light source was a Macbeth daylight lamp with a 75 watt Westinghouse tungsten light bulb. The data acquisition unit was the Tektronix RSS (rapid scan spectrometer) and DPO (digital processing oscilloscope) with minicomputer PDP 11/05 and its accessories. The digital processing oscilloscope contains a signal acquisition unit, a display unit and a processor. The processor which has the ability to digitize an acquired waveform provides an interface with a minicomputer. The rapid scan spectrometer is capable of scanning the optical spectrum from 300 nm (ultraviolet) to 1100 nm (near infrared). The spectrometer uses a Czerny-Turner grating monochromator without an exit slit. The spectral output of the monochromator is focused onto the target of a vidicon tube where the spectrum is stored as an electrical charge image. An electron beam periodically scans across the vidicon target converting the charge image into an electronic signal that is in turn processed by the plug-in unit in the digital processing oscilloscope. The entire optical computation can be achieved by the software programming.

c. Procedure and Design - The execution steps were: (1) obtain energy power spectrum without sample through RSS and store in DPO memory location B; (2) obtain energy power spectrum transmitted through a sample and store in location C; (3) obtain energy power spectrum of ambient (background) light and store in location D; (4) subtract B and C from D and divide C by B and store in location A. The computer program which was presented in a previous report[3] was used to execute the above stops automatically by pushing DPO control panel button #1 or typing "GOTO 100" on the teletype.

RESULTS

Figures 1 to 15 show the spectral transmittance (ST) of samples 1 to 15 respectively. Since the windscreen materials are anisotropic media, the ST is in general a function of the sample thickness. For example, the average transmittance for 6 mm thick UH-1 sample is 90% and for 12 mm is 74%. The average transmittance for 6.82 mm thick U8D sample is 80% and for 13.64 mm is about 58%. The thickness of each sample is shown in Table 1. Also for the purpose of comparison, we placed the T-41 formed sample and the unformed sample on the same page as well as the AG-1G clear sample and the tinted sample.

DISCUSSION

Spectral transmittance (ST) varies from sample to sample. In general, the ST for clear windscreen samples is flatly distributed across the spectrum. Since sample 4, 5, 6, and 15 are colored, their spectral transmission characteristics do not uniformly distribute across the spectrum. For example, in the visible range of the U8D/U8F sample, the ST is about 90% at 500 nm and about 80% at 650 nm. In the T-41 formed sample, the ST is about 80% at 540 nm and only about 60% at 620 nm. The similar situation appears for the tinted AH-1 sample which has only about 55% ST at 600 nm.

On the other hand, the STs for all the samples in the near IR range (from 700 to 1080 nm) possess the following general characteristics: (1) they are relative flat throughout this spectral range; and (2) the average transmittance is from 85% to 92%. We employed the Beckman Model 24 spectrophotometer (made by Beckman Instrument Inc., Fullerton, CA 92634) to obtain the measurement below 400 nm and we also verified some of the data by this method. We notice that the rate of decrement in ST at the lower end of the spectrum varies from sample to sample. For example, at 360 nm, T-42 sample is about 55% while TH-13 sample is 0%. In general, below 350 nm most windscreen samples do not transmit any light at all.

In conclusion, we have investigated spectral transmission characteristics of sixteen Army aircraft windscreen samples. They were from six fixed wing and seven rotary wing aircraft windscreens. For comparison purposes, two samples from the same aircraft (that is T-41 formed edge and unformed edge) were tested. We also measured the spectral transmittances of clear and tinted AH-1G Hueycobra windscreen samples. We have found that the tinted sample has about 27% ST reduction from that of the clear sample across the visible spectrum. This reduction of ST could constitute a dangerous loss of visibility for the aviator, especially during periods of reduced illumination and at night. Furthermore, the variance from a flat spectral transmission would result in distorted color perception by the aviator viewing through the tinted windscreen. Detailed review and discussion on the visual perceptual effect of the tinted windscreen have been available elsewhere[5]. Finally, we would like to point out that CH-54 windscreen material is the same as that of the one used in CH-34 and CH-37. Thus our study has covered most of the current Army aircraft inventory. Further study will be conducted on the windscreens of future generation aircraft such at UTTAS and AAH when those samples are made available to us.

TABLE 1 - SAMPLE THICKNESS

	Fixed Wing Samples	Thickness (in mm)
(a)	O-1 (Bird Dog)	3.35
(b)	OV-1 (Mohawk)	4.26
(c)	U6 (de Havilland)	6.31
(d)	U8D/U8F (Seminole)	6.82
(e)	T-41 Cessna (formed)	3.00
(f)	T-41 Cessna (unformed)	2.50
(g)	T-42 Beech	6.19
	Rotary Wing Samples	
(a)	TH-13 (Sioux)	3.21
(b)	TH-55/OH-6A (1 Cayuse)	2.44
(c)	OH-58 (Kiowa)	2.52
(d)	UH-1 (Iroquois)	6.00
(e)	CH-47 (Chinook)	7.40
(f)	CH-54 (Tarhe)	2.25
(g)	AH-1G (Hueycobra - clear)	4.71
(h)	AH-1G (Hueycobra - tinted)	5.50

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5. Crosley, J.K., "Tinted Windscreens in U.S. Army Aircraft," USAARU Report 68-7, 1968).

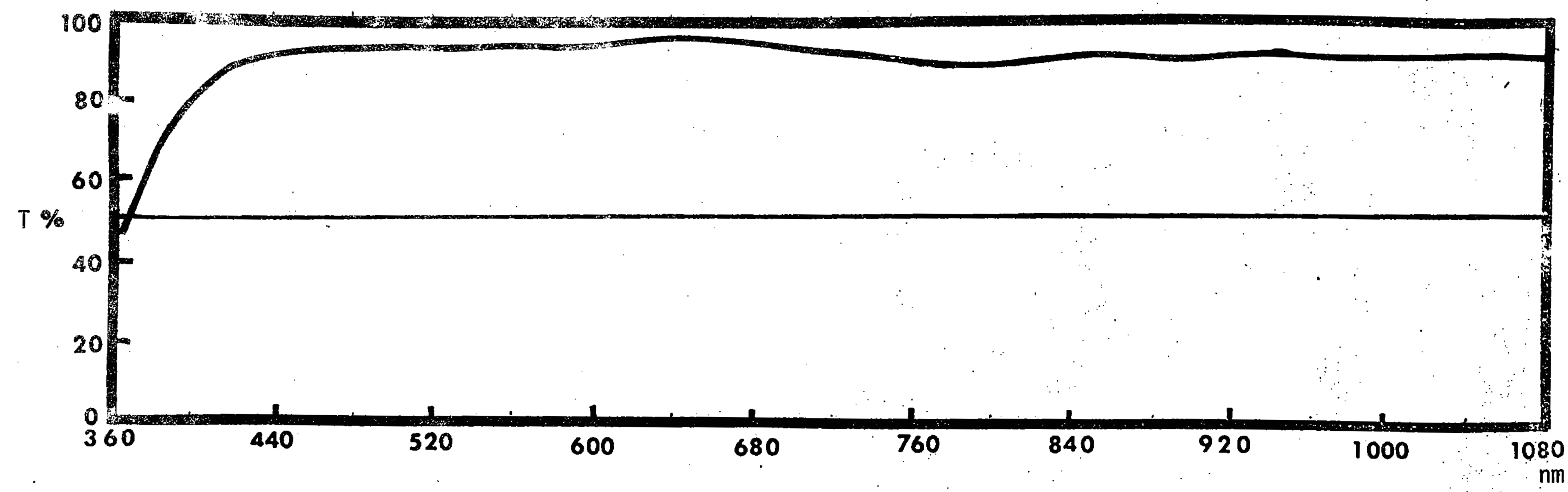

Figure 1: Spectral Transmittance of 01 (Bird Dog)

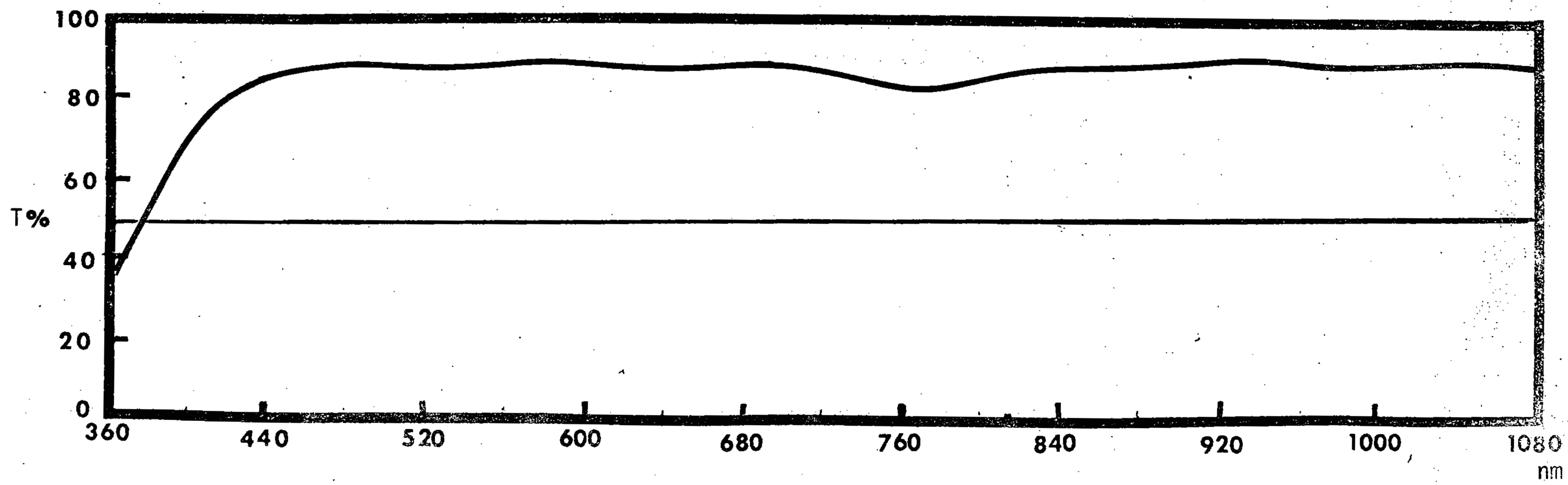

Figure 2: Spectral Transmittance of OV-1 (Mohawk)

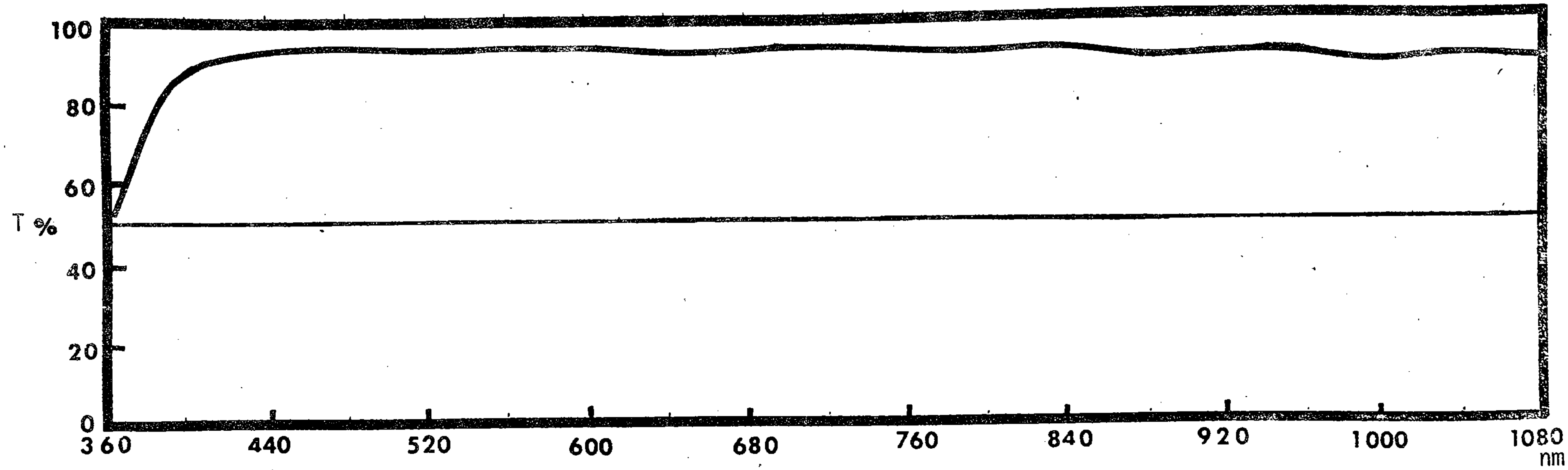

Figure 3: Spectral Transmittance of U6 (De Havilland)

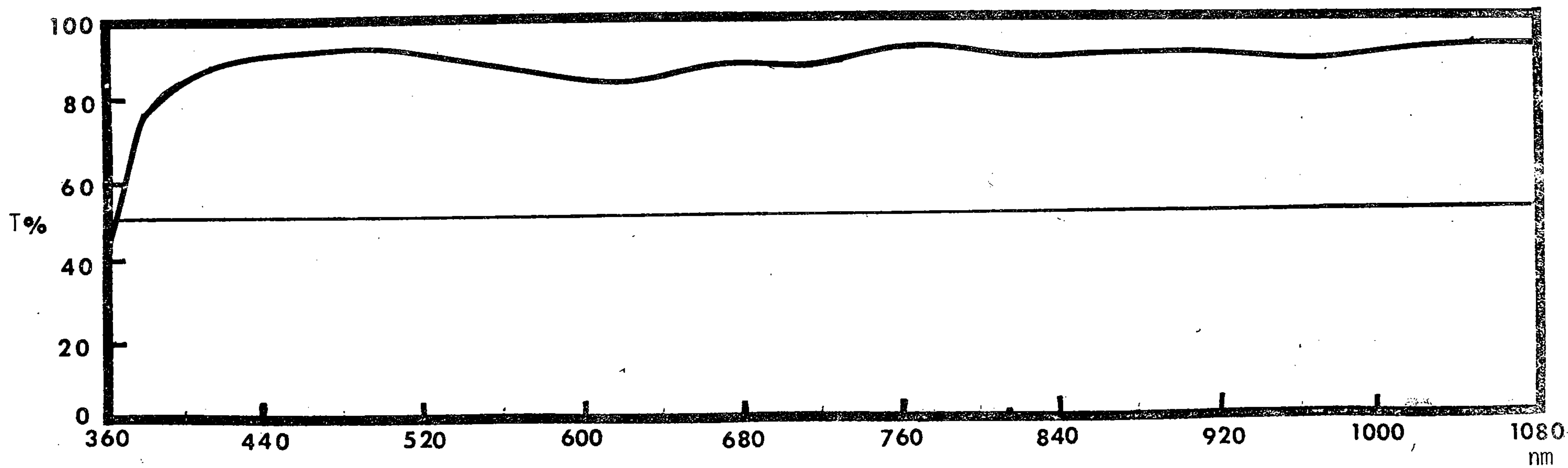

Figure 4: Spectral Transmittance of U8D/U8F (Seminole)

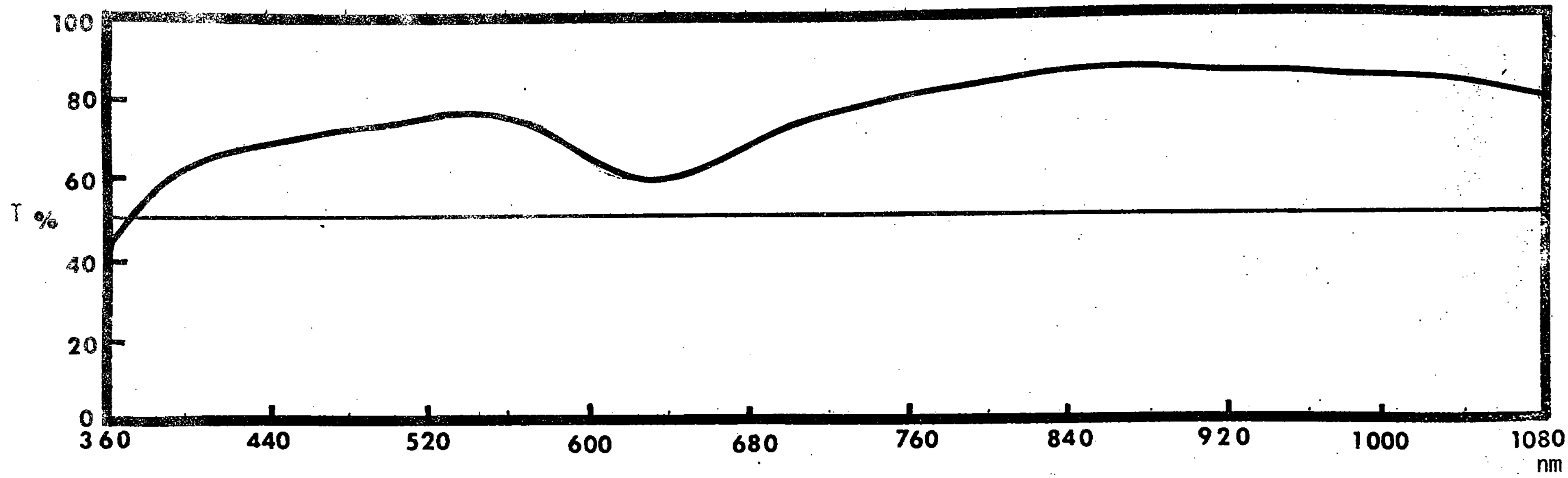

Figure 5: Spectral Transmittance of T-41 (Cessna) formed edge

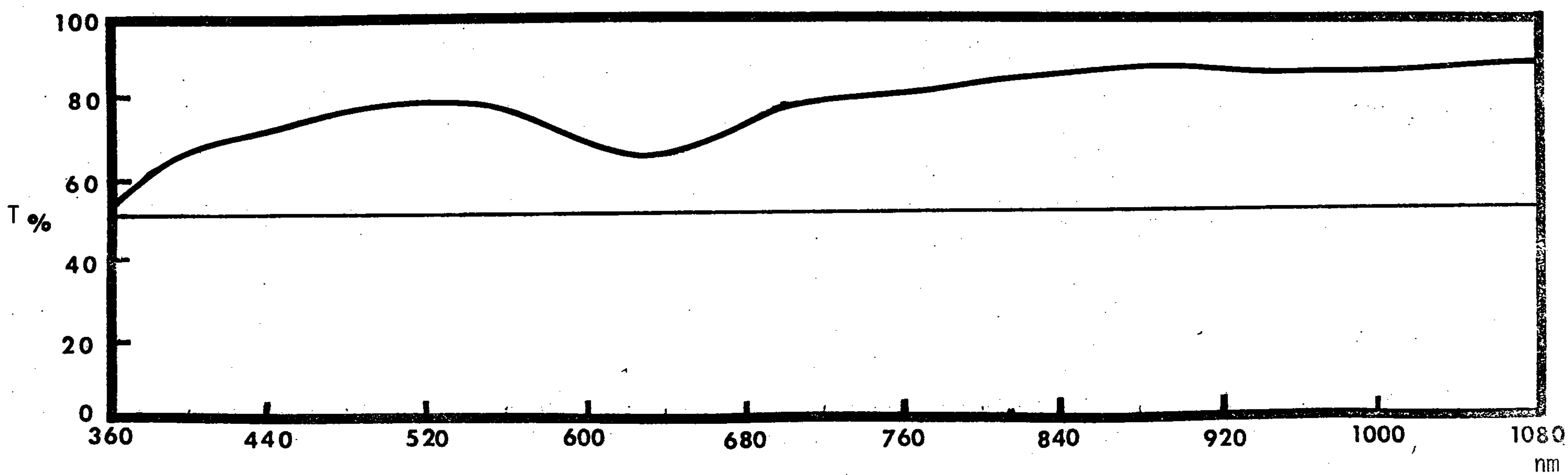

Figure 6: Spectral Transmittance of T-41 (Cessna) flat-unformed edge

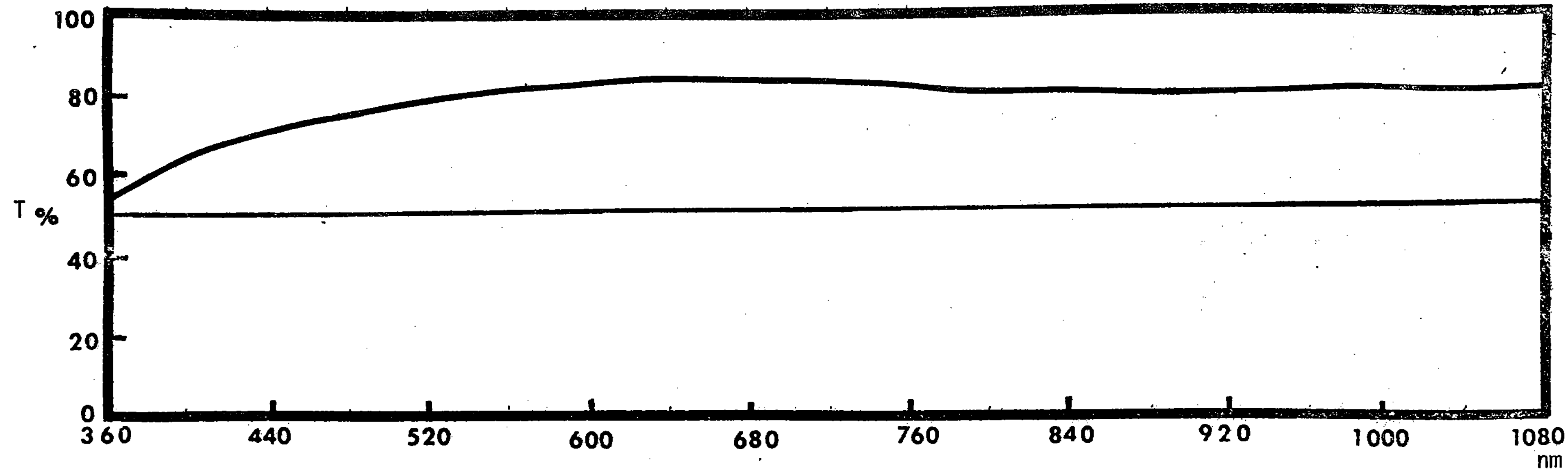

Figure 7: Spectral Transmittance of T-42

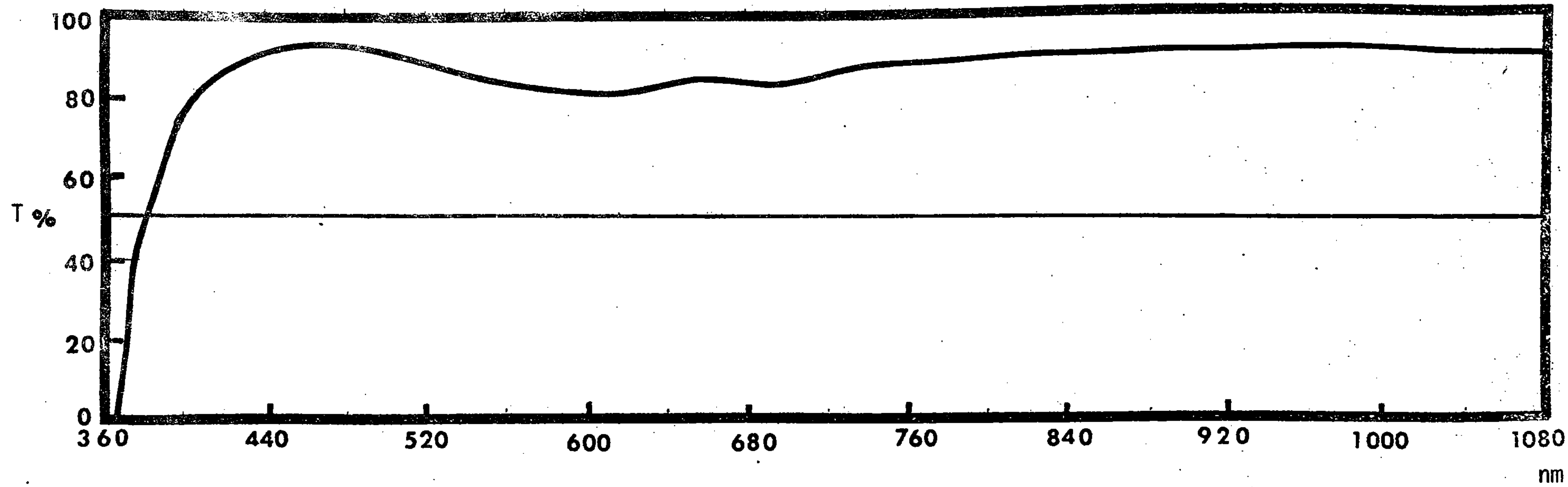

Figure 8: Spectral Transmittance of TH-13 (Sioux)

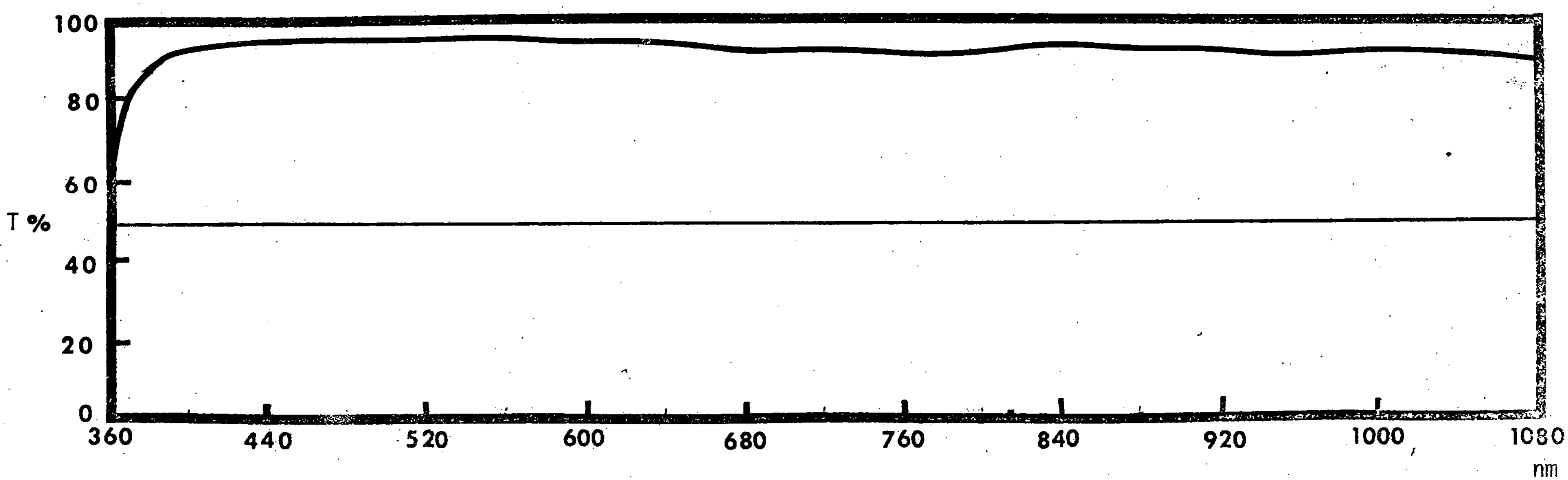

Figure 9: Spectral Transmittance of TH-55/OH6A (Cayuse)

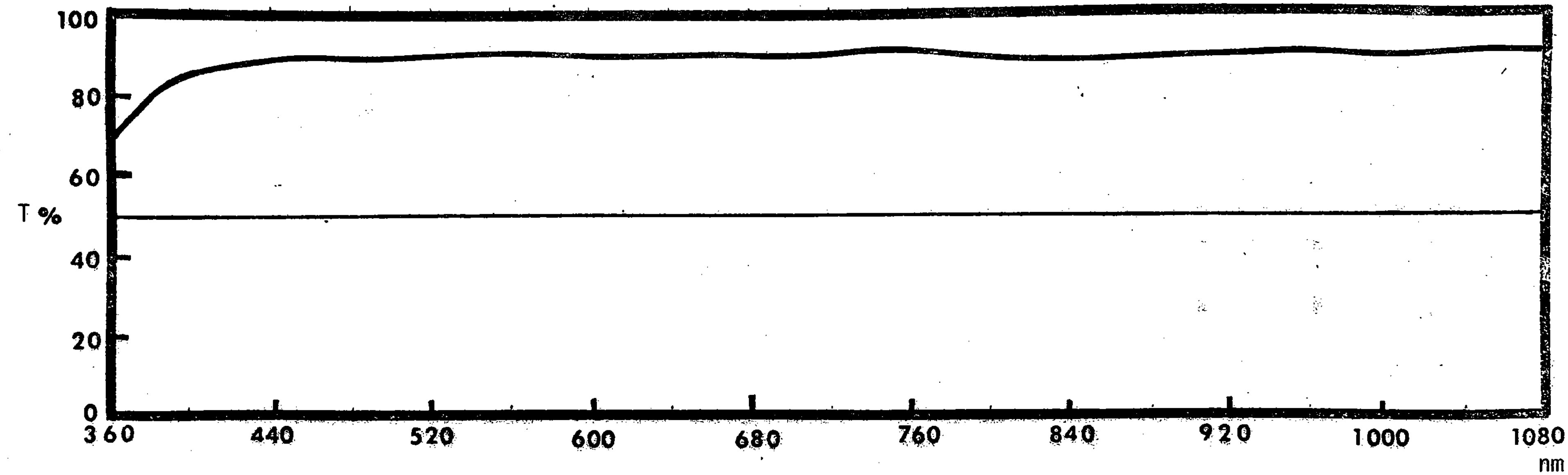

Figure 10: Spectral Transmittance of OH-58 (Kiowa)

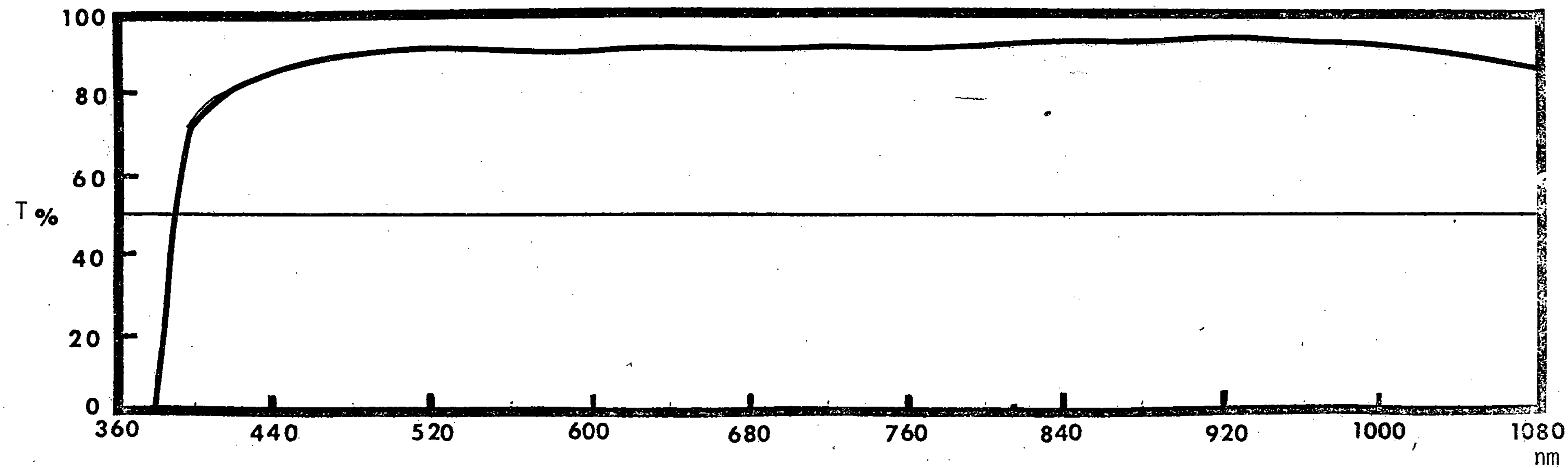

Figure 11: Spectral Transmittance of UH-1 (Iroquois)

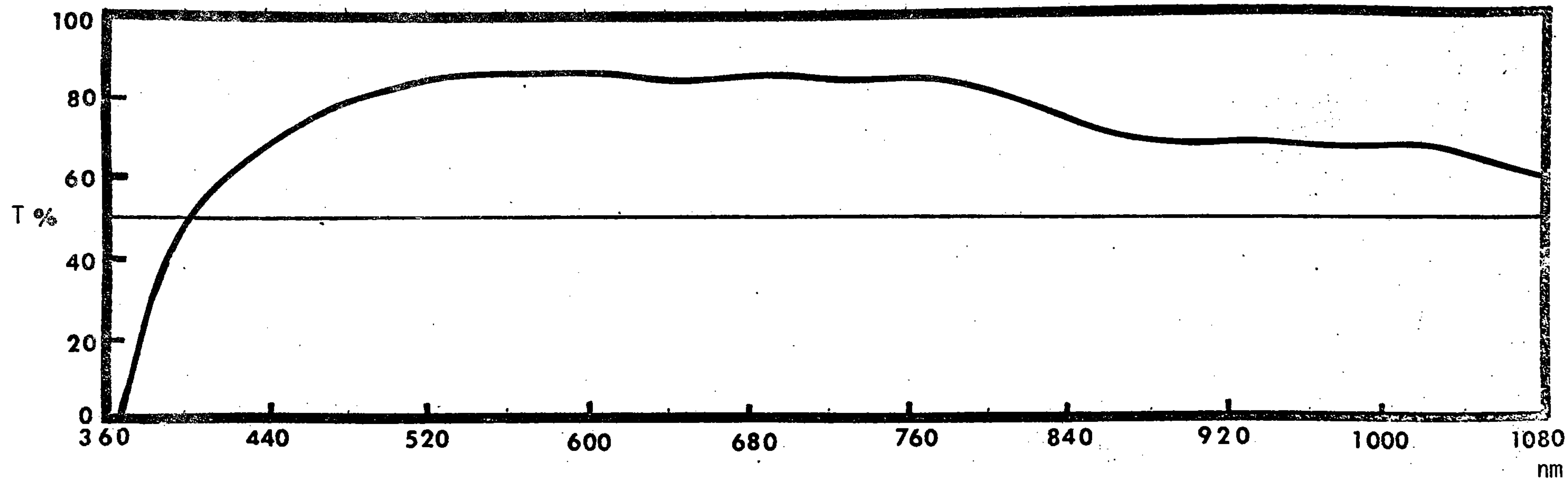

Figure 12: Spectral Transmittance of CH-47 (Chinook)

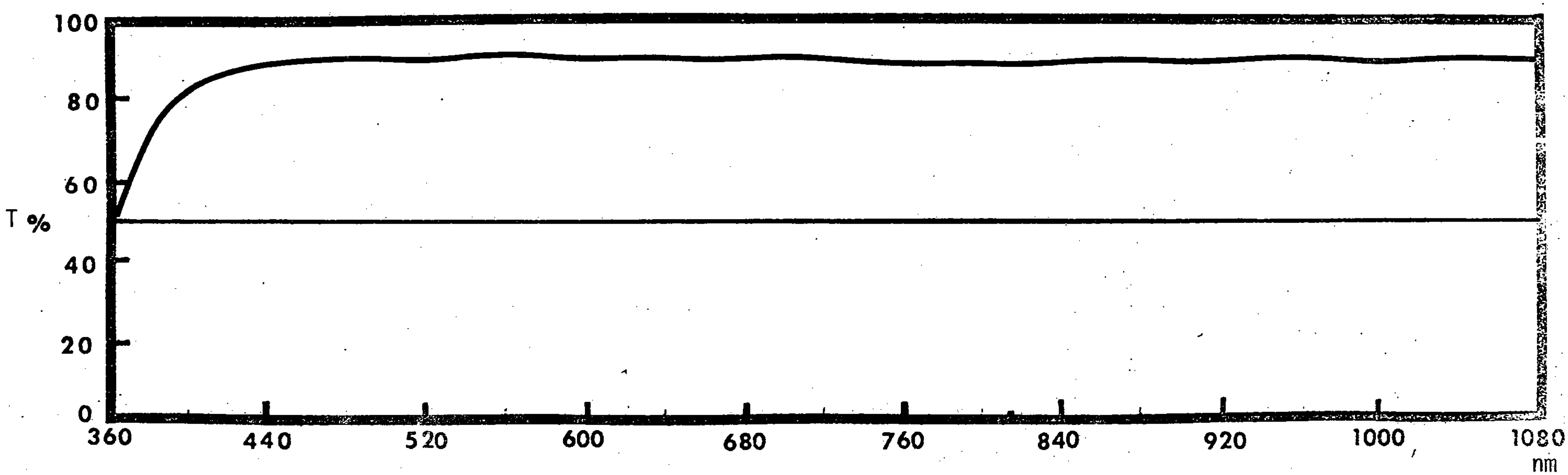

Figure 13: Spectral Transmittance of CH-54 (Tarhe)

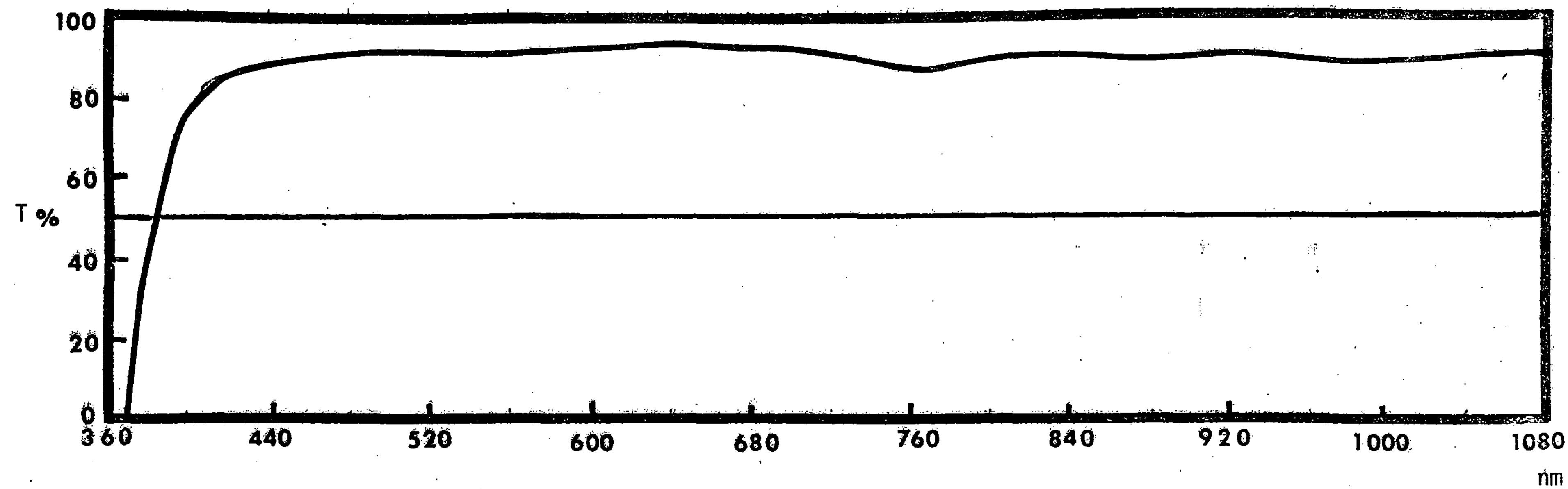

Figure 14: Spectral Transmittance of AH-1G (Hueycobra) (clear)

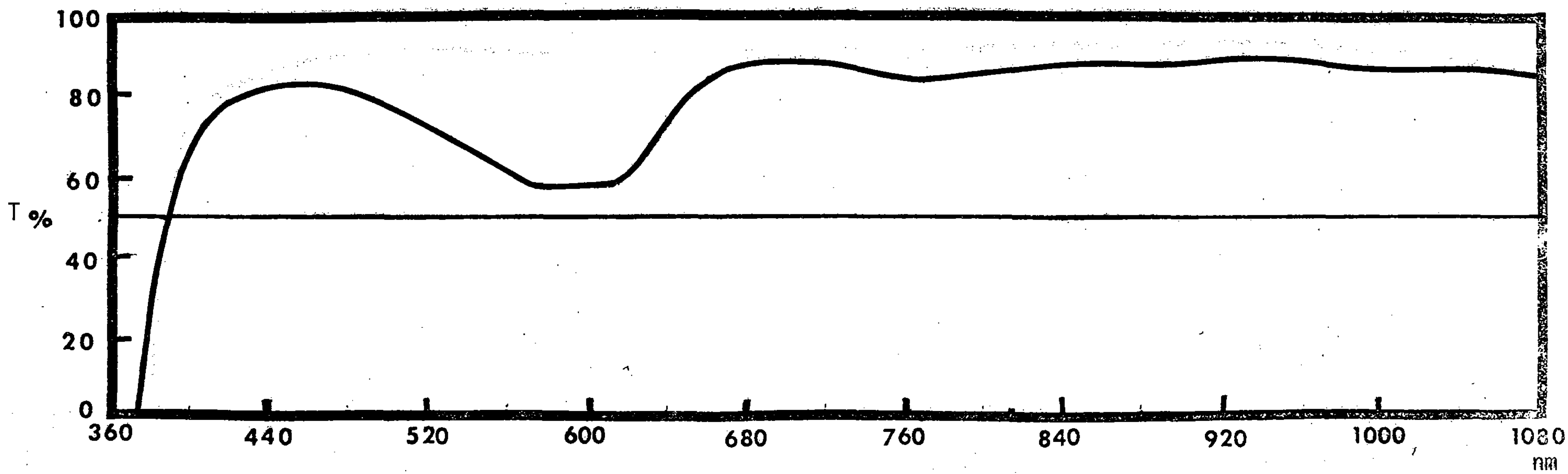

Figure 15: Spectral Transmittance of AH-1G (Hueycobra) (tinted)